Harnessing Water for Sustainable Materials Synthesis through Hydrothermal and Automation Approaches

The chemical industry faces the urgent challenge of decarbonizing synthesis pathways while maintaining access to advanced functional materials. Solvents account for most of the mass and energy input in chemical manufacturing, making solvent innovation a central lever for sustainable transformation. We propose that water, can serve as a near-universal and sustainable reaction medium for the synthesis and processing of chemically diverse materials.

Under hydrothermal and solvothermal conditions, the physicochemical properties of H_2O -- dielectric constant, density, ionic product, viscosity, and solvation characteristics -- change dramatically as a function of temperature. These changes enable modulation of solubility, reactivity, transport phenomena, and phase behavior, effectively expanding accessible reaction space without relying on hazardous organic solvents. Geological processes in the Earth's crust provide compelling precedent: aqueous environments give rise to inorganic, organic, and hybrid compounds across a broad range of bonding motifs and structural hierarchies.

We will present case studies spanning across a range of molecular architectures (small molecules, polymers, networks), order (amorphous, crystalline, semicrystalline), types of bonding (covalent, metallic, ionic), and chemical nature (organic, inorganic, hybrid). Finally, we demonstrate how coupling hydrothermal synthesis platforms with automation and high-throughput experimentation enables systematic exploration of a largely untapped aqueous chemical space. By integrating green solvent principles with digitally accelerated discovery, water-based materials chemistry emerges as a scalable strategy to catalyze sustainable innovation in synthesis and processing.